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INCREASING THE STRENGTH OF PISTONS FOR YAZ DIESELS

N. S. Khanin
Yaroslavl' Automobile Plant

Pistons for the YAZ-204 and YAZ-206 diesel engines are made of cast iron (yield strength: 45-55 kilograms per square millimeter with a relative elongation of 3-6 percent). The iron used has the following chemical composition: carbon, 2.4-2.7 percent; silicon, 1.15-1.25 percent; chromium, up to 0.07 percent; manganese, 0.6-0.9 percent; phosphorus, 0.18 percent maximum; sulfur, up to 0.12 percent. Pearlite components predominate in the microstructure of this iron, and carbon precipitations formed during annealing are edged with ferrite.

The design of the YAZ piston is characterized by the thinness of the head and the cylindrical intermediate section extending from the head to the skirt, and by the extensive use of ribbing. This network of ribs gives considerable cooling surface, making for longer piston life and minimum deformation of the skirt. Heat is conducted away from the head by directing a stream of oil against the internal ribbed surface of the head.

YAZ-204 pistons made during 1947 - 1949 of high-quality homogeneous iron had long life. In a large group of ZIS-154 busses, these pistons were good for no less than 60,000 kilometers, and in some cases were good for 150,000 kilometers. These pistons were good for more than 90,000 kilometers in experimental motors.

In 1949 and the beginning of 1950, many cases of premature failure of YAZ-204 pistons were noted, due most frequently to the formation of a fissure, usually at right angles to the axis of the piston pin, in the head. This type of failure was noted in 92 percent of the pistons examined. Failures due to burns were not frequent in YAZ pistons made in 1949 - 1950. The pistons which had failed after brief service had irregular grain structures and uneven mechanical properties, while those that failed after extended

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service had no defects in their grain structure. The pistons which failed after brief service had decarbonized and oxidized layers, and precipitations of primary graphite in individual grains. The support ribs of the pistons were worst in this respect, and also in mechanical properties. The ring ribs of the piston showed the most strain under a static load.

Temperature tests showed that the highest temperature, 520 degrees at maximum power, was developed at the edges of the piston head. Piston temperature did not exceed 230 degrees at idling speed. The pressure of the oil and correct functioning of the lubrication system had considerable effect on piston temperature. Lowering oil pressure from 1.9 to 1.1 kilograms per square centimeter increased piston temperature 50-70 degrees at maximum speed.

Study of the temperature field showed that considerable temperature stresses appeared in the ribs of the piston during operation. These stresses are opposite in direction to those produced by mechanical loads. As a result of these opposing forces, the amplitude of variations in stress in the ribs increases considerably under operating conditions.

The tensile stress in the vertical ribs considerably increases the negative effect (from the viewpoint of fatigue) of the precipitation of primary graphite, the decarbonization and oxidation of the metal, and other surface defects of the ribs.

Thus, the basic reason why fissures are formed on YAZ piston heads is the collapse of the ribs. Premature collapse of the support ribs is caused by large stresses in alternate directions and low resistance of the piston material to fatigue. After the support ribs collapse, the stress in the ring ribs increases greatly, and operation under these conditions leads to considerable deformation of the head. Further operation produces fatigue fissures on the ring ribs, and the final stage of the process is the formation of a fissure on the piston head. If the rib material is very fatigue resistant, the ribs will not collapse for a very long time, and when they do, it will be due to malfunctioning of the lubrication system of a worn motor.

Two main lines of work were pursued by the Yaroslavl' Plant and by NAMI (Scientific Research Automobile and Automobile Motor Institute) to increase the durability of the pistons: increasing fatigue resistance of the ribs to opposing forces and lowering the stress in the ribs.

The accepted method of making the pistons in 1949 was to cast them in a sand mold with a dry core. The axis of the castings was horizontal. Slow cooling of the ribs in the area surrounding the dry core increased the precipitation of primary graphite and lowered the strength of the ribs. Precipitation of graphite was first decreased by changing the charge: silicon content was decreased from 1.15-1.4 to 1.0-1.25 percent and manganese content was increased from 0.25-0.45 percent to 0.6-0.9 percent. The core forming the ribs was painted with tellurium to hasten cooling. This reduced the precipitation of primary graphite but increased the precipitation of carbon in annealing and caused many inaccurate castings.

Next, NAMI proposed a new method of molding and pouring the pistons with the axis of the piston vertical and the head downward. This method makes the head and ribs the densest parts of the casting. A metallic cooler removes the heat from the ribs, and a ring cooler cools the area containing the piston ring grooves. Connecting members between the support ribs and the piston ring skirt were proposed to avoid porosity in the ribs. This method reduces waste due to porosity from 60 to 10 percent. Consumption of molten metal per casting was cut from 21 to 8 kilograms. The new method reduced the precipitation of primary graphite by half, and the grain structure of the iron began to correspond to that of high-quality pearlite iron.

Testing under compression loads showed considerable increase in strength of the pistons cast by the new method. The breaking point in tons was equal for all the pistons tested.

	/Yield strength in kilograms per square millimeter?7
YAZ pistons made in 1949	36-48
YAZ pistons with tellurium coating of the core	50
Graphitized steel pistons	63
Pistons cast by NAMI method with enlarged rib sections	73
Imported castings	50

Although the graphitized steel pistons showed great strength in the stand test, their ribs were not sufficiently strong when tested in the motor and subjected to alternating loads.

The cross section of the support ribs was enlarged by 15 percent, but this did not increase strength unless the grain structure of the metal was improved at the same time. Best results with enlarged ribs were obtained with force feed lubrication.

Since January 1950, pistons with enlarged rib cross sections have been adopted in the YAZ motor, including those pistons cast by the NAMI method.

The life of the pistons under road conditions depends on the pressure of the oil in the lubricating system. This pressure drops as the oil pump gear wears out. These gears are now being made of 40X improved steel instead of iron to lengthen their life, and their teeth are now shaved instead of being milled. This has tripled their life, and they are now good for a minimum of 100,000 kilometers.

Stand testing of the pistons with enlarged ribs cast by the NAMI method showed that protracted (more than 250 hours) operation was possible at maximum volume power up to 33 horsepower per liter, and piston power up to 0.41 horsepower per square centimeter. The number of work cycles with this load was 6 million. It may be considered that fatigue breakage of the ribs of these pistons has been eliminated at this load.

Results of operating the YAZ-200 truck and the ZIS-154 bus with the NAMI pistons and with pistons having larger rib cross section (coupled with tellurium coating of the cores) shows that their strength has increased considerably over that of the former pistons. Trucks have driven 65,000 kilometers using experimental models of these pistons, and the tests are continuing.

The NAMI method of casting the YAZ pistons is now being adopted in mass production.

In spite of this, care must be exercised in the operation of the YAZ-204 and YAZ-206 diesels. If the engine is operated after score marks appear on the cylinder sleeves or after the injector gets out of adjustment burns will occur on the piston head and circular fissures will appear. If the engine is operated with insufficient oil pressure or lubricated with the wrong kind of oil (without complex supplements), circular fissures will appear.

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Research by the Yaroslavl' Automobile Plant and scientific organizations has the following goals:

1. To use high-strength and heat-resistant material in existing and future piston designs.

2. To intensify cooling of the piston, especially of the fringes of the head.

3. To reduce stress in the ribs by changing their shape.

4. To reduce the possibility of seizing.

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